ERIC Document Resume	See Instruction Sheet	DATE OF RESUME	DATE RECEIVED

A. PUBLICATION DATA

1. ERIC NUMBER	2. ORIGINATOR CONTROL NO(S).	3. IDENTIFICATION NO.
ED002391	N.A.	2231

DO NOT WRITE IN SPACE BELOW

4. AUTHOR(S): Ash, Philip and Jaspen, Nathan

5. TITLE OF DOCUMENT ABSTRACTED: Optimum Physical Viewing Conditions for a Rear Projection Daylight Screen

6. PUBLICATION TITLE: N.A.

7. EDITOR(S): N.A.

8. PLACE OF ORIGIN
ORG. Pennsylvania State College
ST. Philadelphia, Penna.
CITY, STATE
TELE. EXT
INST/LOC CODE

9. PUBLISHER OR SOURCE: Pennsylvania State College Philadelphia, Pennsylvania

10. VOL.	11. PAGES	12. MO./YR.	13. TOTAL PP.
N.A.	N.A.	10/53	19

MICROFILM COPY AVAILABLE YES ☒ NO ☐

COPYRIGHT GRANTED YES ☐ NO ☒

COPYRIGHT RELEASE FILED YES ☐ NO ☐

TYPE OF REPORT
PROPOSAL ☐
IN-PROGRESS ☐
FINAL ☒
FOLLOW-UP ☐

OTHER ERIC REFERENCES:

ERIC SATELLITE CODE

B. INDEXING DATA

14. SUBJECT AREA

15. TYPE OF ENDEAVOR: Report

16. INDEXING TERMS (6-12)

achievement	teaching aids	instructional film		
audiovisual aids	cabinet-type projector	teaching methods		
equipment	teaching methods	films		
	viewing conditions			

17. ABSTRACT (MAX. 250 WORDS)

An experiment designed to discover whether there were differences in learning which could be attributed to differences in room illumination, viewing angle, and distance from the screen as they related to the cabinet-type projector was presented. Participants were 721 trainees at the Great Lakes Naval Training Station. The task chosen was the assembly of the breech block of an antiaircraft gun. Although most Navy trainees could not perform the task without instruction, they learned the assembly in a few minutes with an appropriate film. Half of the trainees saw the same film under daylight illumination conditions; the other half saw the film under darkened room conditions. A test room was set up with 50 seating positions at varying angles of view and at varying distances from the screen. Following a film showing, the trainees were tested on their ability to assemble breech blocks.

The evidence indicated that performance was better under conditions of daylight in the optimum viewing area. Optimum viewing conditions were within thirty degrees of the center line. Optimum viewing positions were within twelve screen widths of the screen. The foregoing factors should be taken into consideration in training situations when trainees practice a skill during a film showing.

ERIC No.

18. SOURCE OF ABSTRACT

C. FUNDING DATA

19. SUPPORTING ORGANIZATION	20. DIVISION OR DEPT.	21. CONTRACT NO. / PROJECT NO.
	22. TOTAL COST OF PROJECT	
	23. DURATION OF PROJECT	U.S. Department of Health, Education, and Welfare Office of Education

ERIC Form 1

2231

U. S. DEPARTMENT OF HEALTH, EDUCATION AND WELFARE
Office of Education

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ED 002391

TECHNICAL REPORT - SPECDEVCEN 269-7-37

OPTIMUM PHYSICAL VIEWING CONDITIONS FOR A REAR PROJECTION DAYLIGHT SCREEN

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SPECDEVCEN Project 20-E-4
Contract N6onr-269

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12 October 1953

For the Special Devices Center:

Harry Sosnoski

Harry Sosnoski, Captain, USN
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Instructional Film Project
Distribution List

ED002391

SPECIAL DEVICES CENTER
OFFICE OF NAVAL RESEARCH
HUMAN ENGINEERING DEPARTMENT

Problem:

The cabinet-type projector makes it possible to present films under conditions of relatively high surrounding illumination. It reduces the need for blackout shades and curtains and allows for concurrent participation exercises. This experiment was designed to discover whether there are differences in learning which can be attributed to differences in (1) room illumination, (2) viewing angle and (3) distance from the screen

Results:

In skill learning involving practice along with a film showing:

1. Performance is better under conditions of daylight in the optimum viewing area.

   (a) Optimum viewing conditions were within thirty degrees of the center line.

   (b) Optimum viewing positions were within twelve screen widths of the screen.

Recommendations:

In training situations in which it is desired to have the trainee practice a skill during a film showing, the best results can be obtained if:

1. A cabinet type projector or equivalent is used since it permits daylight viewing.

   a. Under these circumstances the trainee should not be more than thirty degrees from the center line nor more than twelve screen widths from the screen.

Project Engineer

Head, Research Branch

Head, Psychological Research
and Development Division

OPTIMUM PHYSICAL VIEWING CONDITIONS FOR A REAR PROJECTION DAYLIGHT SCREEN

by

Philip Ash and Nathan Jaspen

The Instructional Film Research Program
The Pennsylvania State College

INTRODUCTION

The 16mm projector and screen constitute a device of great importance in very many training programs. Particularly in the Armed Forces, the film, because it can be used to present a compact body of information or ideas in a standard manner to large groups of men, is increasingly relied upon to facilitate training. Standard equipment, however, lacks certain virtues that would appreciably simplify the use of films. The typical projector-amplifier-screen combination is not easily portable; it requires large viewing rooms and trained set-up personnel, and it is not too well adapted to impromptu field use, as for example in somewhat shaded daylight.

The continuous loop cabinet type projector such as the Telekit[1] is designed to provide this flexibility (Figures 1 and 2). In its present form, it is primarily intended for use with relatively small groups. The device comprises a small rear-projection screen (13" x 18") behind which is used a 16mm sound projector equipped with a very short (1/2") focal length lens and an image-reversing system. The refractive character of the screen, which is made of a new plastic, is such that the image retains clear definition at a rather wide viewing angle. An additional feature of the equipment is the inclusion for optional use, of a pre-loaded continuous film loop holder of 800 foot capacity. The loop device permits indefinite repetition of a sequence 800 feet or less in length. Starting and stopping of the loop can be controlled by a hand switch. The entire equipment (including amplifier and speaker) is readily portable in a single case.

The rear projection arrangement allows for the possibility of a high degree of flexibility. To the extent that it permits projection under conditions of relatively high ambient illumination, it reduces the need for blackout shades and curtains and allows for concurrent participation exercises (such as performing an assembly while watching the screen) that require substantial amounts of light at the trainee's desk. On the other hand, the small size of the screen imposes a limitation on the size of the viewing group.

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[1] A product of Television Associates, Inc., Michigan City, Indiana.

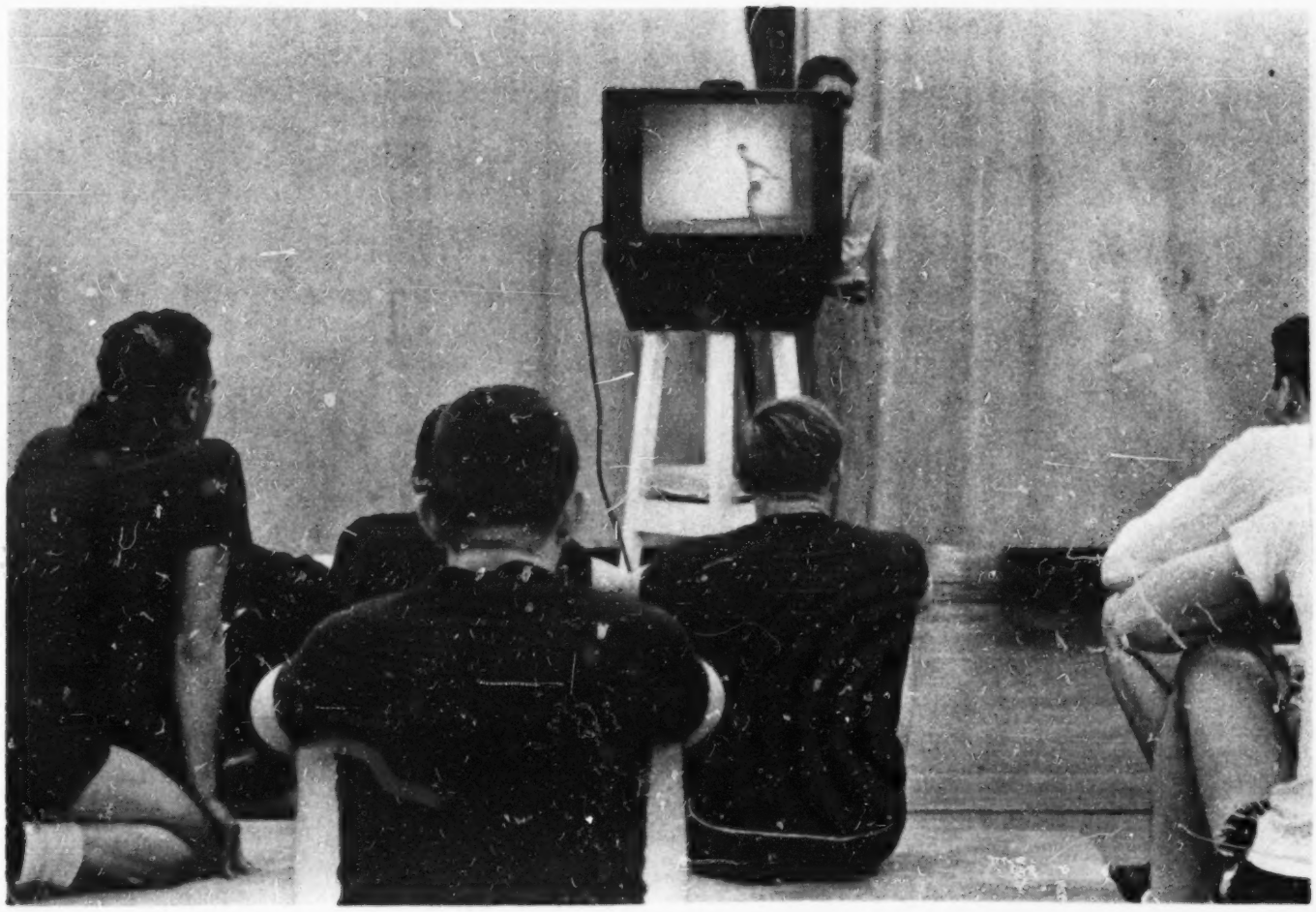

Figure 1 The equipment in use in a training situation.

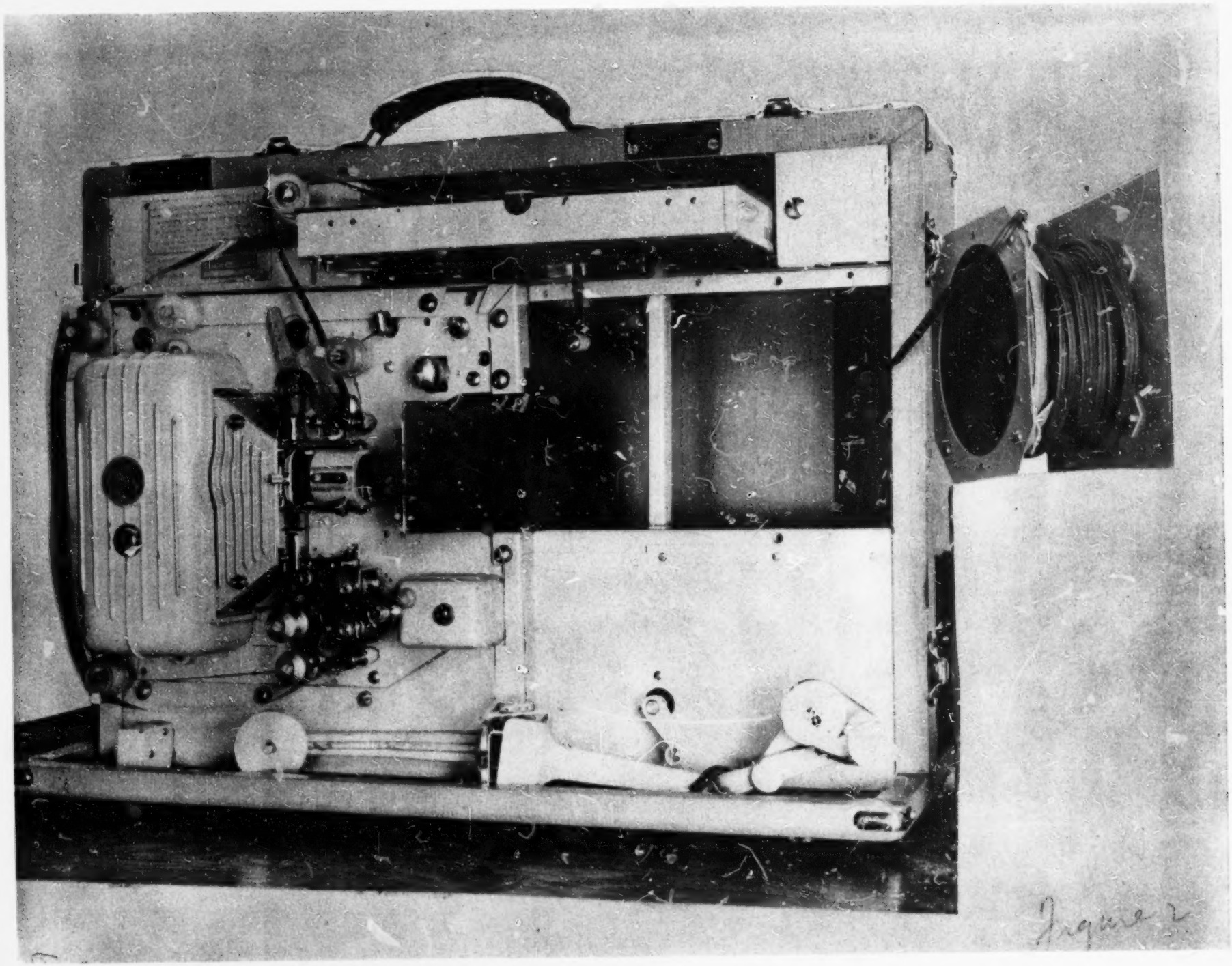

Figure 2

Figure 2 Rear view of the projection equipment showing the projector, image reversing mirror and 800' film loop magazine. A 200' magazine is also available.

The Society of Motion Picture and Television Engineers has established a standard which states that "the width of the screen should be not less than 1/6 of the distance from the center of the screen to the most remote seat . . ." (1). On this basis, an 18" wide screen would permit a viewing area no deeper than nine feet. Even a 90° sector, 45° each side of the projection axis, would include only 64 square feet. Allowing for some distance between the front row and the screen, this area would accommodate only 8-10 people, and those not too comfortably. It is, therefore, important to determine whether this viewing distance applies in fact, as the maximum usable one, to this type of equipment.

Previous research by Gibson (2) has shown that, for a standard size screen and projector, there is no appreciable falling off in performance as angle of view and distance from the screen are increased up to certain limits. In these studies, a large size screen was employed. Up to an included angle of 90° (45° on each side of center) there was no falling off in test performance. The maximum screen distance tested was about seven screen widths. It was also found that relatively high room illumination had little or no negative effect. However, the small size of the cabinet projector's screen and its rear projection feature make it difficult to generalize from Gibson's results to this type of equipment.

In the present investigation, therefore, it was decided to study the effects on learning of (1) viewing angle, (2) distance from the screen, and (3) room illumination as these apply to use of the cabinet type of projector.

EXPERIMENTAL DESIGN

Specifically, the experiment was designed to answer the following questions:

1. What are the optimum and maximum usable viewing distances for the Telekit?

2. What are the optimum and maximum usable viewing angles?

3. What are the effects of daylight, as compared with a darkened room, on viewing angle and distance?

To answer these questions, an experiment was designed to measure objectively the differences in learning which could be attributed to differences in viewing angle, differences in distance from the screen, and differences in room illumination.

A film on assembly of the breech block of the 40mm anti-aircraft gun was shown to groups of Navy trainees seated at systematically varied angles and distances from a screen. The amount of light in the room was systematically varied with angle of view and distance from the screen. Learning, objectively measured by a performance test, was related to angle, distance and room illumination. It was possible to determine the relationships among distance, angle, and amount of light.

Experimental Population

Seven hundred and twenty-one trainees at The Great Lakes Naval Training Station took part in the experiment.

The Experimental Task and Film

The task chosen was the assembly of the breech block of the 40mm anti-aircraft gun (Figure 3). Most Navy trainees are unfamiliar with this assembly, cannot perform the task without instruction, but can, with an appropriate film, learn the assembly in a few minutes.

The film used to teach this task was a nine-minute film showing two demonstrations of the assembly step by step. The rate of development of the film was slow.

Definition of Variables

Angle of view was simply the angle between (1) a line from a given viewing position to the center of the screen and (2) a line perpendicular to the center of the screen.

Distance from the screen was simply the distance, in inches, from a given viewing position to the center of the screen. (This must be considered in relation to picture size, and can most usefully be expressed as a function of screen width.)

Room illumination was the amount of light in the room during projection. There were two conditions of room illumination in the experiment: (1) daylight: blackout shades removed from windows and (2) darkness: blackout shades in position over windows.

(The projector was located so that under the daylight condition, direct sunlight from the windows did not fall on the screen.)

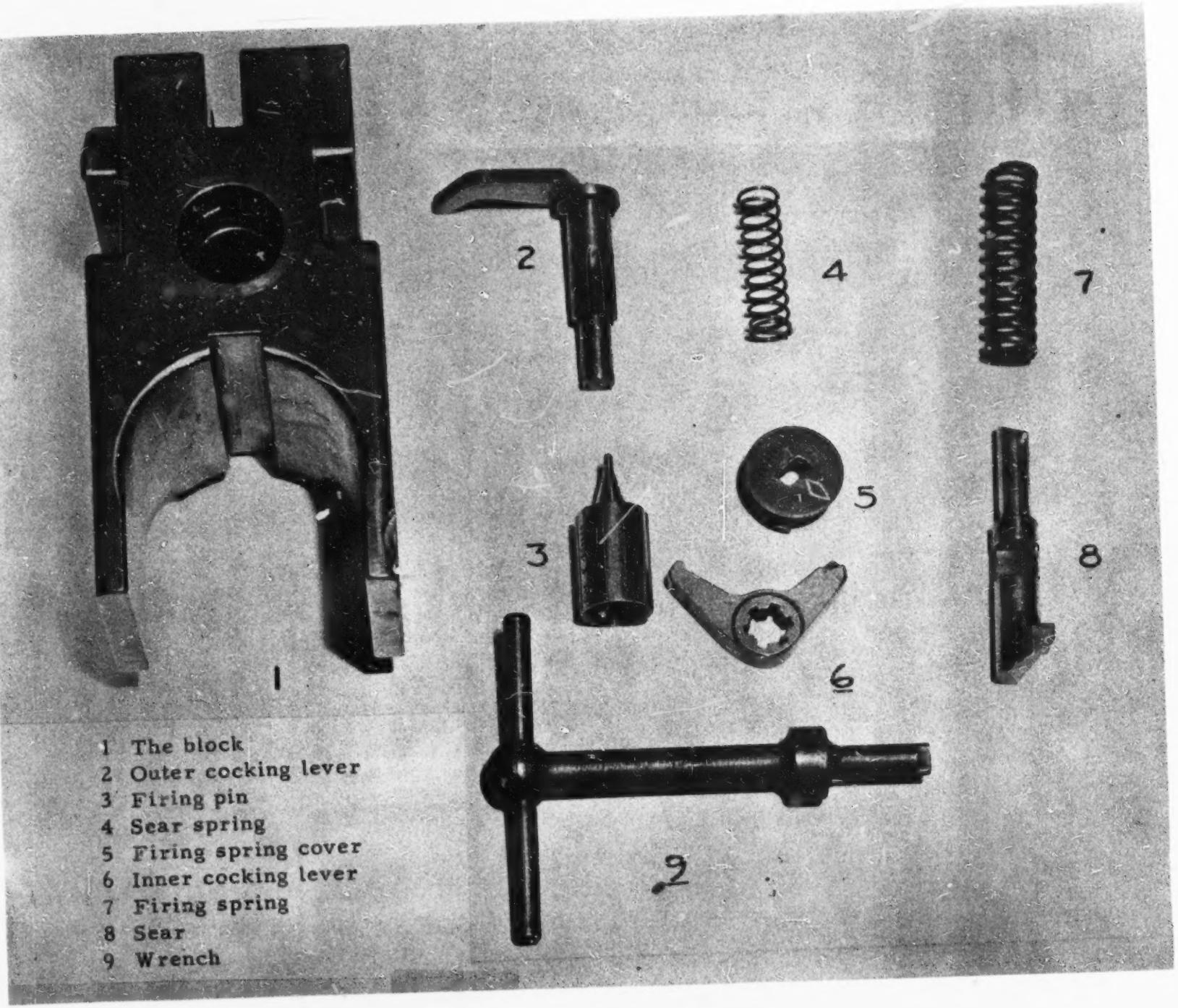

Figure 3 Breech Block, 40mm Anti-Aircraft Gun Disassembled

Test Procedure

To study the effect of angle of view and distance from the screen, a test room was set up as indicated in Figure 4. Arcs were drawn at six-foot intervals from the projector, and radii were extended at intervals of 0^{o} through 60^{o}. Seats were arranged along the arcs. The viewing area was therefore a pie-shaped sector, one-sixth of a circle. In all, 50 seating positions were studied, as shown in the figure.

The same film on assembly of the breech block was shown to all trainees. Half of the population of 721 men were tested under daylight illumination conditions and half under darkened room conditions. An average of more than seven men per position for each condition of lighting was available.

Following a film showing, the men were directed to "test stations." Six long tables were arranged in the room. Each table had from four to six "test stations." At each station, a breech block, set-up photograph, stop watch, pencil, and an oil rag were placed. A responsible proctor was assigned to each station.

Proctors were trained to set up disassembled breech blocks in a standard manner, to operate stop watches, and record data.

When trainees were in their respective test stations, the head proctor gave a signal to begin assembly of breech blocks. The test period was six minutes long. As soon as a man finished (or when the test period ended), the proctor noted whether the man passed or failed and recorded his time score, and dismissed him.

Data Analysis

The data for the speed scores are summarized in Table 1, and the pass-fail scores in Table 2 (see Appendix). The downward trend as distance and/or angle is increased is clearly evident — beyond 30^{o} and 18 feet. Up to these points, the position means are too variable to yield positive evidence of a trend.

A grouping of the viewing positions into four areas or sectors on the basis of the boundaries indicated in Figure 4 (0^{o}-30^{o} vs $37\ 1/2^{o}$-60^{o} and 6-18 feet vs 24-36 feet) clarifies the effect of angle and distance. In Table 3, the mean speed scores and mean per cent passing are given for each of the four areas, under both dark and daylight viewing conditions. In the optimum area, performance is better under conditions of daylight; in the other areas, performance is better under conditions of darkness. Furthermore, increasing the distance from the screen results in much sharper loss in performance than increasing the angle of view, and the relative loss is much greater under daylight than under dark viewing conditions.

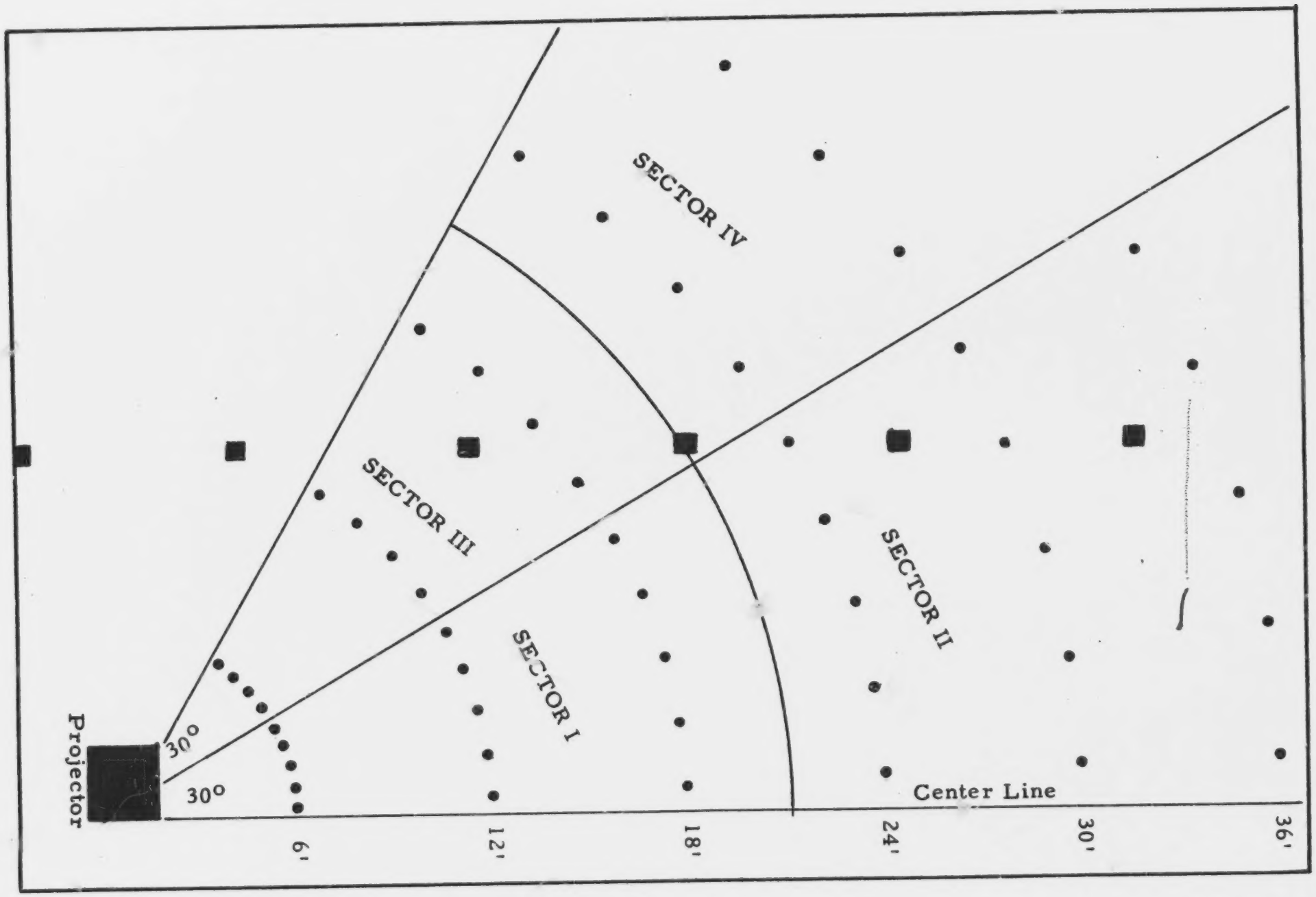

Figure 4

Layout of Experimental Room for Study of Angle of View and Distance from Screen

The data was subjected to an analysis of variance (Table 4) which corroborates these observations. Significant loss is attributable to increasing the angle of view or distance from the screen. While the difference between daylight and dark viewing is insignificant over all the observations, the degree of light interacts significantly with angle of view, and probably interacts with distance from the screen.

RESULTS

The significant findings are shown graphically in Figures 5 and 6.

1. There is an optimum area for viewing this rear-projection screen. This area includes a cone 60° wide (30° on each side of the center line) and 18 feet (12 screen widths) deep. Performance of trainees who sat within this sector was better than performance of trainees who sat outside of it.

In the optimum area (up to 30°, up to 12 screen widths), performance is better under conditions of daylight; outside these limits, in the other sectors studied, performance is better under conditions of darkness. Furthermore, increasing the distance from the screen results in much sharper loss in performance than increasing the angle of view, and the relative loss is greater under daylight than under dark viewing conditions. The degree of light interacts significantly with angle of view, and probably interacts with distance from the screen.

CONCLUSIONS

The data should be interpreted to mean that:

1. There is an optimum area for viewing the Telekit screen. This area consists of a cone 60° wide (30° on each side of the center line) and 18 feet (12 screen widths) deep.

2. In this optimum viewing area, performance following daylight film viewing will probably be better than, or at least as good as, performance following viewing the screen in the dark.

3. If a substantial fraction of the audience is placed outside this optimum area, overall group performance will probably be better under conditions of viewing in the dark.

4. If the optimum area is to be extended, the losses will be less if the angular size of the area is increased than if the distance from the screen is increased.

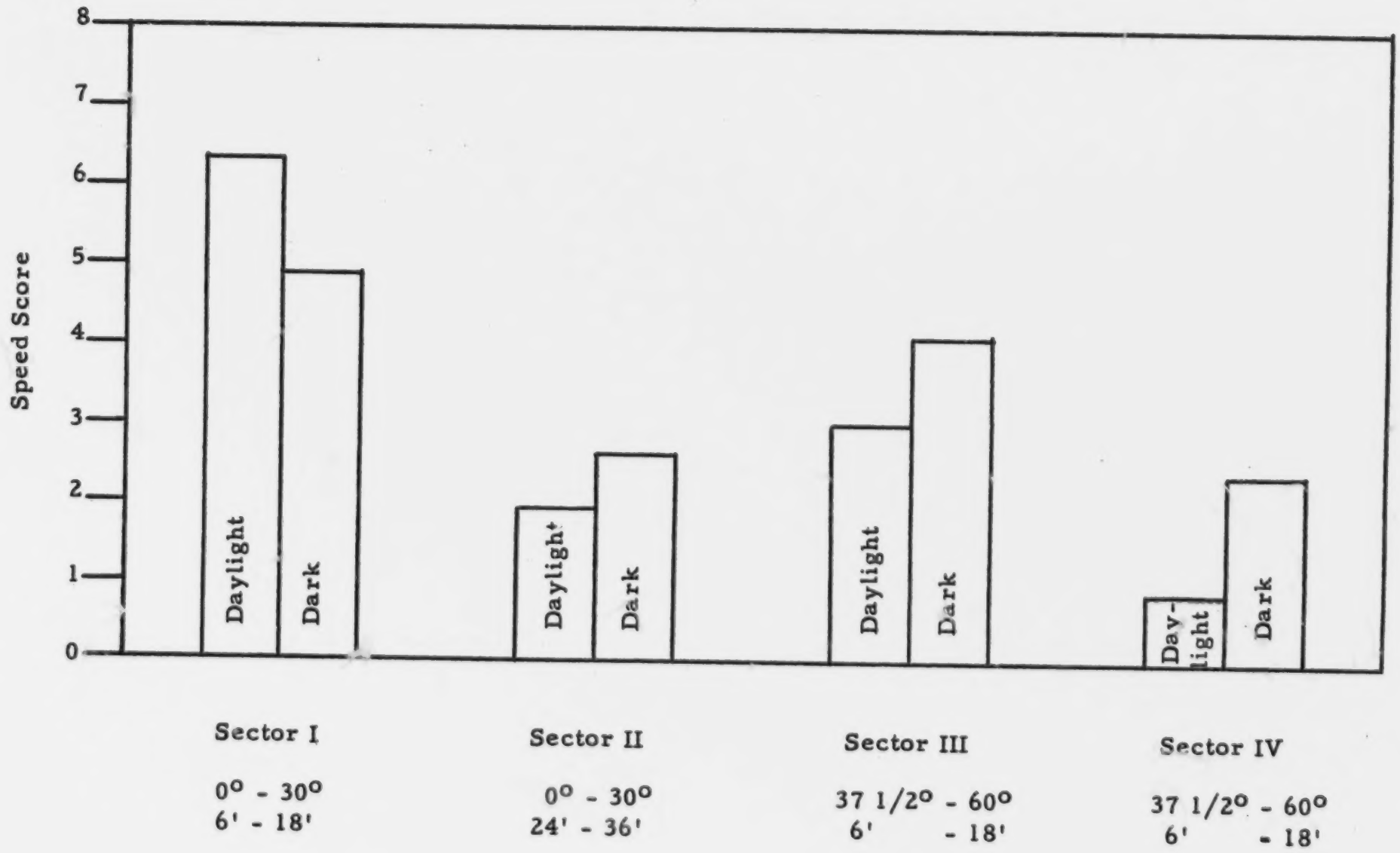

Figure 5

Mean Speed Score by Sector
Under Daylight and Dark Viewing Conditions

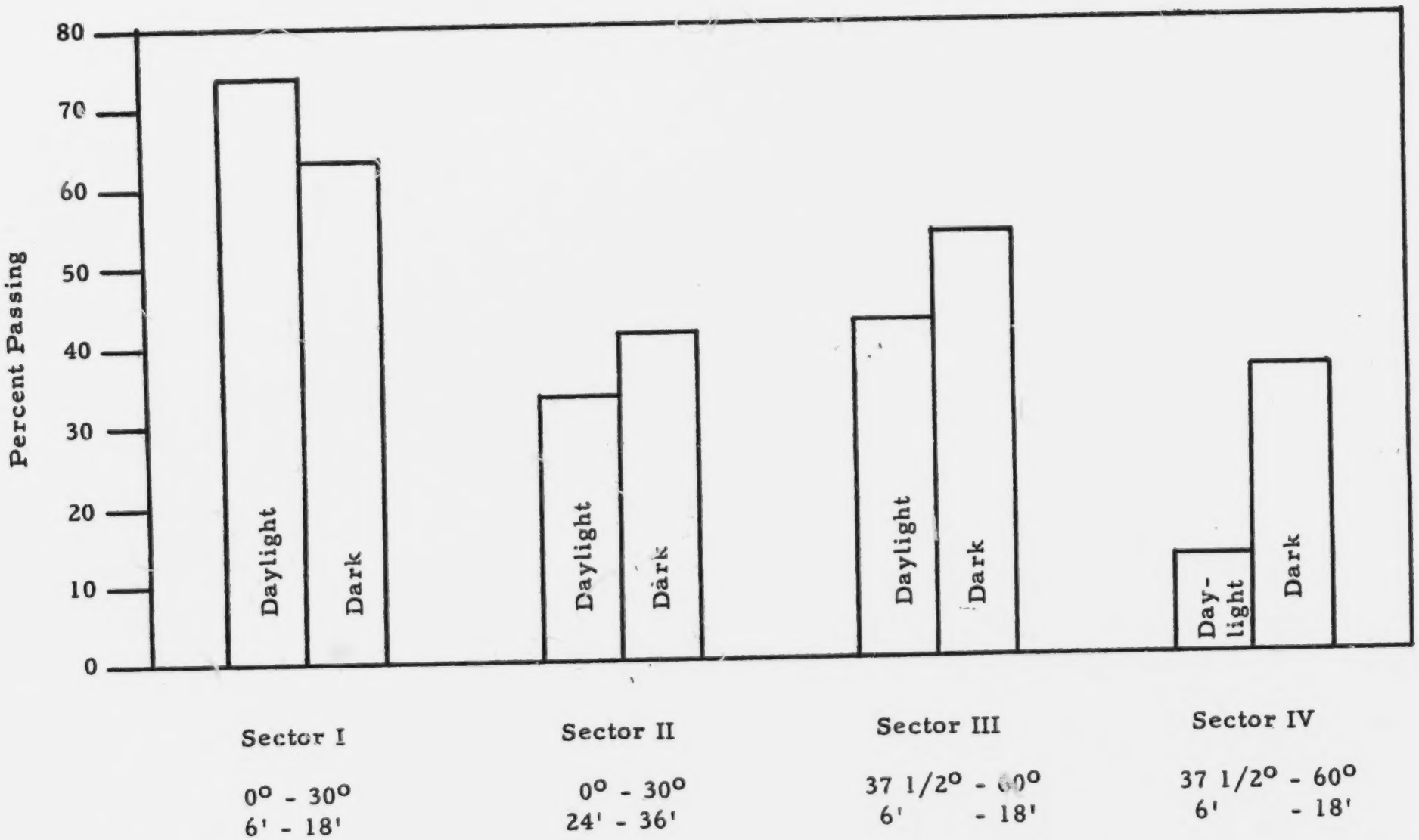

Figure 6

Percent Passing by Sector
Under Daylight and Dark Viewing Conditons

IMPLICATIONS

1. Within a relatively large area, which can seat between 30 and 40 individuals, the Telekit rear projection equipment can be used, under daylight conditions, to achieve a satisfactory level of learning.

2. If it is necessary to extend this area, it is better to increase the angle of view rather than increase the distance from the screen. If angle of view is increased (or if distance from the screen is increased), learning is likely to be higher under darkened room conditions rather than daylight conditions.

3. The findings of this study would seem to be relevant to the viewing of television, where size of screen and viewing conditions are comparable to those of the Telekit.

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1. Society of Motion Picture Engineers, American standard dimensions for theatre projection screens. September 10, 1948. New York, American Standards Association Inc., 1948.

2. Gibson, J. J. (ed.) Motion picture testing and research. A. A. F. Aviation Psychology Program, Report No. 7. Washington, D. C., Government Printing Office, 1947.

APPENDIX

TABLE 1

MEAN SPEED SCORES FOR EACH VIEWING POSITION, UNDER DAYLIGHT AND DARK VIEWING CONDITIONS

A. Daylight

Angle (degrees)	Distance (feet) 6	12	18	24	30	36	Mean Speed for Angle
0	7.86	6.71	8.13	3.83	6.12	1.43	5.680
7 1/2	4.38	4.86	7.75	.50	.86	1.22	3.262
15	7.80	5.38	3.14	1.14	1.40	1.67	3.422
22 1/2	4.87	4.13	7.57	5.00	1.75	1.38	4.117
30	8.25	8.13	6.60	1.43	0	2.00	4.402
37 1/2	3.71	5.13	2.43	1.00	1.67	1.00	2.490
45	3.17	.83	6.20	.75	.43	-	2.276
52 1/2	5.00	3.38	3.57	0	0	-	2.390
60	.88	1.67	1.00	1.40	-	-	1.237
Mean Speed for Distance	5.102	4.469	5.154	1.672	1.529	1.450	

B. Dark

Angle (degrees)	Distance (feet) 6	12	18	24	30	36	Mean Speed for Angle
0	5.63	3.83	5.12	2.71	3.67	2.00	3.827
7 1/2	5.86	5.25	5.14	3.71	2.63	2.50	4.181
15	1.00	7.57	4.78	4.00	2.86	.78	3.498
22 1/2	2.86	5.25	5.00	2.22	.43	1.33	2.848
30	4.43	8.14	3.13	5.43	4.75	.67	4.425
37 1/2	3.57	4.13	3.50	3.50	3.33	1.43	3.243
45	2.33	5.89	5.50	3.75	2.38	-	3.970
52 1/2	3.57	5.80	6.25	1.43	2.86	-	3.982
60	3.57	3.00	2.33	.78	-	-	2.420
Mean Speed for Distance	3.647	5.429	4.528	3.059	2.864	1.452	

TABLE 2

PERCENT SUCCEEDING IN ASSEMBLY FOR EACH VIEWING POSITION, UNDER DAYLIGHT AND DARK VIEWING CONDITIONS

A. Daylight

Angle (degrees)	Distance (feet) 6	12	18	24	30	36	Mean Percent for Angle
0	71.4	66.7	87.5	42.9	62.5	37.5	61.42
7 1/2	50.0	71.4	75.0	12.5	25.0	22.2	42.68
15	83.3	100.0	42.9	25.0	50.0	50.0	58.53
22 1/2	50.0	62.5	100.0	83.3	25.0	25.0	57.63
30	87.5	75.0	83.3	25.0	0	14.3	47.52
37 1/2	66.7	62.5	42.9	25.0	0	12.5	34.93
45	50.0	16.7	50.0	12.5	14.3	-	28.70
52 1/2	57.1	50.0	71.4	0	0	-	35.70
60	12.5	14.3	14.3	33.3	-	-	18.60
Mean % for Distance	58.72	57.68	63.03	28.83	22.10	26.92	

B. Dark

Angle (degrees)	Distance (feet) 6	12	18	24	30	36	Mean Percent for Angle
0	55.6	71.4	62.5	28.6	57.1	33.3	51.42
7 1/2	71.4	62.5	75.0	42.9	50.0	50.0	58.63
15	16.7	71.4	77.8	62.5	50.0	20.0	49.73
22 1/2	42.9	62.5	57.1	40.0	14.3	16.7	38.92
30	71.4	85.7	66.7	71.4	62.5	22.2	63.32
37 1/2	50.0	75.0	33.3	37.5	33.3	16.7	40.97
45	42.9	66.7	57.1	62.5	37.5	-	53.34
52 1/2	42.9	60.0	75.0	42.9	42.9	-	52.00
60	62.5	25.0	50.0	11.1	-	-	37.15
Mean % for Distance	50.70	64.47	61.61	44.38	43.45	26.48	

TABLE 3

MEAN SPEED SCORE AND MEAN PERCENT PASSING
FOR FOUR VIEWING SECTORS, UNDER DAYLIGHT
AND DARK VIEWING CONDITIONS

Sector	Mean Speed Score		Mean Percent Passing	
	Daylight	Dark	Daylight	Dark
0°-30°, 6-18 feet	6.371	4.866	73.767	63.373
0°-30°, 24-36 feet	1.982	2.646	33.347	41.433
37 1/2°-60°, 6-18 feet	3.081	4.120	42.367	53.367
37 1/2°-60°, 24-36 feet*	.781	2.433	12.200	35.550
Mean of Sector Means	3.054	3.516	40.420	48.431

* Omits four extreme positions cut off by room walls. The sector means are, as a result, probably somewhat inflated.

TABLE 4

ANALYSIS OF VARIANCE OF PERFORMANCE BY VIEWING SECTOR ANGLE, VIEWING SECTOR DISTANCE, AND CONDITION OF ILLUMINATION, FOR BOTH SPEED AND PASS-FAIL SCORES

	Speed Scores		Percent Passing	
Source of Variation	Mean Square	F	Mean Square	F
Angle (0-30° vs. 37 1/2-60°)	43.47	17.87***	6853.88	21.02***
Distance (6-18 ft. vs. 24-36 ft.)	164.30	67.56***	17818.24	54.65***
Light (Dark vs. Daylight)	5.01	2.06	1502.47	4.61*
Angle x Distance	10.06	4.14*	302.44	< 1
Angle x Light	18.26	7.51**	1966.55	6.03*
Distance x Light	11.33	4.66*	1390.96	4.28*
Angle x Distance x Light	3.54	1.46	54.99	< 1
Error (92 df)	2.43		326.04	

*** Significant beyond the 0.1% level of confidence
** Significant at the 1% level of confidence
* Significant at the 5% level of confidence